The Economics of 4R BMP Implementation and Emissions Reductions from Fertilizer

An Industry Perspective on Financial Implications of the 30% Nitrous Oxide Emission Reduction Target

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Sponsored in Partnership by Fertilizer Canada and Canola Council

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Dr. Heaney has worked as an agronomist and soil scientist nationally and internationally for over 35 years. He completed his education at the University of Alberta, earning his PhD (Soil Science) in 2001. He is a Professional Agrologist and holds a practice license from the Alberta Institute of Agrologists covering the practice areas of Crop Production; Greenhouse Gas Assessment and Management; and Biosystems, Biosolids, Compost and Manure Management. Dan is also a Certified Crop Advisor with a 4R Nutrient Management Specialization.

Over his career, Dan has worked in the academic, government, and private sectors. He recently retired from Farmers Edge Inc. where he was Vice President Global Agronomy. Dan remains actively involved in the digital agriculture space as an independent consultant. His current work involves development of expert systems for nutrient management; and implementation of 4R Nutrient Stewardship programs; as well as facilitating the adoption of on-farm carbon offset protocols such as the 4R Climate Smart in Canada and internationally. Dan holds appointments as an Acting Member of Alberta's Natural Resources Conservation Board and as a Research Associate with Plant Nutrition Canada. He also serves as a director on the Certified Crop Advisor Prairie Province Board and as the Disciplinary Hearing Director for the Alberta Institute of Agrologists.

Authors' Note

Fertilizer nitrogen management is incredibly complex and in the final analysis site specific. Crop producers and their advisors must synthesize knowledge derived from science and experience and integrate economics, logistics, and agronomics to manage crops within a highly variable growing environment. Each farm and in fact each field offers a unique set of challenges that change from one year to the next. 4R Nutrient Stewardship provides an integrated approach to nutrient management in cropping systems. The 4R approach is based on scientific principles, but relies on local knowledge derived from research, demonstration, and experience to adapt and develop appropriate BMPs at the farm level. Fertilizer Canada along with partners like the Canola Council have championed the adoption of 4R BMPs within a Climate Smart approach to sustainable intensification for over 15 years.

This study, as in any study that attempts to forecast a future state, required us to make assumptions on future trends in crop prices, fertilizer prices, inflation rates etc. Given the disruption of global supply chains due to Covid 19 and more recently the war in Ukraine, assumptions were made within a highly volatile environment. When developing economic trends out to 2030, we assumed a gradual return to more normal market conditions for crop and fertilizer prices and a decline in the overall inflation rate to the pre-Covid range. Time will tell if this holds true or if the current disruption is the new normal.

This paper is written primarily for the industry to stimulate discussion and is not presented in a scientific peer review journal or scientific monograph style. We have kept references in the main text to a minimum but will include some key scientific references on the effectiveness of BMPs in on-line supplemental material. Modelling produces voluminous data sets and we have also moved some of the detailed financial and analytical data at the regional level to appendices.

Canadian crop farmers have over the past three decades steadily increased total production, maintained the financial viability of the Canadian farm, and still made considerable progress in reducing the carbon footprint of Canadian crops. Recent work from Saskatchewan suggests that on Prairie farms crop production may be approaching net zero and from 2005, the baseline for Canada's Paris commitment, to 2016, sectoral emissions dropped 53%, more than is required to meet the 2030 Paris target.[1] Adoption of reduced tillage systems and improved nitrogen management have been the two major drivers reducing the carbon footprint of Canadian crops. Adoption of climate smart practices is not just a western phenomenon, farmers in Ontario are highly invested in split application of nitrogen fertilizer with available data suggesting it is practiced by a third or more of corn growers in the province. Inexplicably, neither net reductions from carbon sequestration nor 4R BMP adoption are captured and credited to crop production in the current version of the National Inventory Report.

One thing that has become increasingly apparent through the Covid and Ukraine crisis is that the global food supply and food security is fragile. World populations continue to grow and with it not only demand for more food but higher quality and healthier food. Canada is a major exporter of food as is Ukraine, and recent events have shown consequences of supply side disruption. Climate change is a serious issue that will have a significant impact on food security for many countries. While agriculture must do its part in limiting the impacts of climate change, emission reduction strategies that imperil the growth of world food supply and the financial futures of farmers and their families are simply not tenable.

[1] *Awada L, Nagy C, Phillips PWB (2021) Contribution of land use practices to GHGs in the Canadian Prairies crop sector. PLoS ONE 16(12): e0260946. https://doi.org/10.1371/journal.pone.0260946*

Executive Summary

The Government of Canada has targeted a 30% reduction in on-farm nitrous oxide emissions from synthetic nitrogen (N) fertilizer by 2030. Using estimates from the 2022 National Inventory Report (NIR), total nitrous oxide emissions from fertilizer N reached 11.8 $MtCO_2e$ per year in 2020 setting the emission target at 8.3 $MtCO_2e$ per year in 2030. A reduction of 3.5 $MtCO_2e$ compared to the 2020 baseline.

One key component to reaching any emission reduction target is the implementation of 4R Nutrient Stewardship Best Management Practices (BMPs) on farm. To date there are approximately six million verified 4R acres under the Designation and Certification programs in Canada.

In this study, we use a series of regional scenarios for major Canadian cropping systems to build out a path forward to 2030 based on broader implementation of 4R Nutrient Stewardship BMPs and examine the financial implications and feasibility of the reaching the 30% target. To this end, we developed integrated economic and nitrous oxide emission models for major cropping systems in five regions and compared the effects of increased 4R BMP adoption rates on the regional crop production economy and nitrous oxide emissions from fertilizer. The GHG modelling used the N rate driven 2022 NIR methodology with modifications derived from the 4R Climate Smart Protocol to account for the influence of source, time, and place in reducing N_2O emissions. The BMPs included in the model were selected based on broad applicability across N fertilized crops and sufficient information available to estimate implementation costs.

There were three scenarios explored in this study:

1. A no yield increase scenario was initially compared to a yield increase scenario using reasonable if somewhat optimistic increases in BMP adoption out to 2030.
2. The second scenario looked at a yield increase that included a moderate increase in N fertilizer rate to support the additional yield. While substantial emission reductions were achieved, the 30% target was not reached in either scenario. Yield increase trends have been the norm in Canadian crop production and are necessary for farmers to maintain their financial viability.
3. A third scenario was developed, using the yield increase scenario values as the starting point, to estimate the levels of BMP adoption required to meet the emissions reduction target against the background of increasing crop yield. In this third scenario, 4R BMP adoption rates were increased iteratively until 30% reduction was achieved in each region.

Summary of Key Outcomes and Trends

The following observations and results are constrained by the assumptions used in the economic and emission estimating models used in this study.[2]

- The study encompasses Ontario, Quebec, and the Prairies with the Prairies broken into three regions based on soil zone, climate, and cropping system difference.
- The regions modeled represent over 90% of fertilizer N applications to crops inventoried in the 2022 NIR and over 90% of baseline 2020 nitrous oxide emissions attributable to fertilizer N.
- 4R BMP adoption rates in the 2020 baseline ranged between 5-25% depending on the BMP, the crop, and the region. These were progressively increased depending on the BMP, the crop, and

[2] A full explanation of the assumptions and the modelling approach are available in the full report.

the 2020 baseline adoption rate reaching 2 to 8 times higher by 2030 in the no yield and yield increase scenarios.

- As reported in the 2022 National Inventory Report (2022 NIR), emissions from fertilizer N in the 2020 base year occur largely on annual crop land (96%) with only 4% attributable to fertilizer use on perennial crops.

No Yield Increase Scenario

- At the adoption rates used in the no yield increase scenario, the cumulative total cost of BMP implementation reached $3,420 million in 2030 and resulted in a cumulative reduction of 14.4 $MtCO_2e$ or $237/$tCO_2e$ reduced.
- Substantial annual reductions in nitrous oxide emissions from fertilizer were achieved reaching 2.50 $MtCO_2e$ per year by 2030 at a gross cost of $495 million per year and a net cost of $357 million over the 2020 baseline cost.
- Costs of BMP adoption were offset in part by savings in fertilizer costs based on the reductions in nitrogen rates linked to the various BMPs. When yield was kept constant net annual costs to crop growers were still a substantial $109 million or $43.68/$tCO_2e$ reduced.
- Costs per tCO_2e reduced were lowest in the high emission intensity corn-soybean-winter wheat systems in Ontario and Quebec and highest in the lower emission intensity canola-cereal-pulse systems in the Wet Prairie West Region of Alberta and Saskatchewan.
- Fertilizer emission reductions were accompanied by significant downward pressure on profitability in the no yield scenario. While this trend was driven in large part by the declining crop prices and increasing costs built into the model scenarios, the cost of BMP adoption was also a significant factor. Most regions experienced a negative net income by 2030 with contribution declines ranging from 34% to 47% from the peak of the 2022 year.
- The cost of BMPs at a farm level would be different than the averages of the region analysis shown above. The implementation of the full set of BMPs at farm level would cost approximately $34 per acre to implement in 2022 and rise to $43 per acre in 2030. This would represent between 7% and 10% of operating costs and would be a significant cost especially in the face of declining profitability unless further offsetting reductions in fertilizer and seed costs could be found without affecting yield.

Yield Increase Scenario

- In all regions the estimated contribution margins in 2030 increased with increasing yield ranging from $48 to $83 per acre higher than the no yield increase scenario. This represents a total $4.3 billion per year increase in contribution margin for the combined regions in the 2030 year over the no yield increase scenario. This represents a substantial increase in revenue for farmers and highlights the financial benefit of the longstanding trend of increasing yields.
- With increased yield, emission reductions in 2030 reached 1.6 $MtCO_2e$ with cumulative reduction of 10.4 $MtCO_2e$. These reductions, while still considerable are respectively 36 and 28% than those estimated in the no yield scenario.
- The yield increase scenario substantially slowed the erosion in contribution margin and supported farm profitability. For example,
    - Increasing corn and winter wheat yields in Ontario increased contribution margins by **$57 per acre or 23%.** This represents an additional **$351 million** of revenue in 2030 for Ontario producers.

    - For corn the impact of increased yield was substantial as the contribution margin increased $144 per acre or 118% in 2030 as compared to no yield increase. This equals **$305 million** of additional revenue on the total acreage of corn in Ontario for the 2030 year.
    - Increased canola and cereal yield in the Wet Prairie West region increased the contribution margin by **$85 per acre or 105%** in 2030 as compared to no yield increase. This equates to **$2.2 billion** of additional revenue on the total acreage of canola and cereals in the Wet Prairie West region for the 2030 year.
    - For canola the impact on increased yield increased the contribution margin by **$160 per acre or 118%** in 2030 compared to the no yield increase scenario. This equals **$1.7 billion** of increased revenue on the total acreage of canola grown in the Wet Prairie West region.
- Since BMP adoption rates and net BMP costs were near constant in both the yield and no yield increase scenarios but the tonnes reduced was substantially lower in the latter, the average cost per tCO_2e reduced increased by approximately 1.57-fold. The change in costs per tCO_2e reduced were substantially higher in Ontario (18-fold increase) than they were in Quebec and the Prairie Regions where increases ranged from two to four times higher.

Yield Increase and Adoption Rates Required to reach Reduction Targets

- Following the above, and assuming that growers would not be interested in reduction strategies that eroded their margins, adoption rates were increased for the yield increase scenario until the 30% emission reduction was achieved. Results varied by region but reaching the 30% reduction essentially required adoption of multiple advanced 4R BMPs on nearly every acre of N fertilized crop.
- In Ontario and Quebec adoption rates of 100% would need to be achieved by 2030 to meet the 30% reduction. In the western regions adoption rates of between 60% and 70% would need to be achieved. It should be noted that the baseline 2020 adoption rates in Ontario and Quebec were higher than the western regions, meaning that the magnitude of the change needed in the western regions are as significant as in the eastern regions.

One caveat should be noted here. The model used the average of the 2020-2022 fertilizer price across all years, which by historical standards is high. If fertilizer price was to fall below this price or growers were less aggressive in reducing N rates, the cost savings from the fertilizer reduction would decrease, the net cost of BMP implementation would increase from those shown above, and the cost per tCO_2e reduced would also increase substantially. The underlying assumption in the model is that BMP adoption will increase Nitrogen Use Efficiency (NUE) and allow N rate reductions. There is a finite limit on NUE and stacking BMPs may not allow for linear rate reductions without yield loss.

Key Findings and Conclusions

- The challenge of reducing emissions from fertilizers to 30% below 2020 levels by 2030 is immense. There are very few growing seasons between now and then and reaching 30% is not realistically achievable without imposing significant costs on Canada's crop producers and potentially damaging the financial health of Canada's crop production sector.

- Canada will have to balance the goal of reducing greenhouse gas emissions from fertilizer application against farm profitability, economic growth and global food security. There is no free lunch in food production.
- This study shows that Canada can balance both its economic and environmental goals. With an increased yield, GHG emissions can be reduced by 14% by 2030 - a cumulative reduction of 10.4 $MtCO_2e$.
- Adoption of 4R N management practices can substantially reduce fertilizer N_2O emissions but it will take very close to 100% adoption of advanced practices on N fertilized crops to reach the 30% reduction target by 2030.
- To maintain net income, the cost of BMP adoption must be offset by savings in operational costs such as reduced fertilizer use or increased revenue from higher crop prices and/or increased yield. The results of this study suggest that cost savings alone cannot compensate for BMP implementation and increased crop revenue and/or external incentives will be required to cover the costs of practice change.
- Without increasing yield and revenue, the cost of implementing emission reduction strategies would in combination with inflationary pressures undercut the profitability of Canadian crop production.
- There will likely be little interested from growers in emission reduction strategies that risk the economic sustainability of their farms.
- Despite these trade-offs, Canada's farmers can use 4R Nutrient Stewardship principles to effectively reduce their carbon footprint.
- Environment and Climate Change Canada must integrate 4R Nutrient Stewardship into the National Inventory Report to ensure that progress towards a target can be monitored appropriately.
- The government appears committed to using international protocol with the NIR which follows the UN Intergovernmental Panel on Climate Change's standards for estimating and reporting emissions. This does not take into consideration improvements in farm-level nitrogen management creating an inaccurate picture of emissions from fertilizer.
- Progress in measuring, verifying, and reporting (MVR) against reduction goals is limited by the availability of high resolution and accurate farm activity data. Government needs to substantially increase investment in this area and develop systems that accurately capture on-farm data.
- Increasing intensity of crop production to meet growing domestic and international demand will limit the amount of reductions that can be achieved and increase the cost per tonne of reductions.
- The results of this study suggest that there is potential for significant downward pressure on contribution margin and net farm incomes, if crop prices decline and yields are not increased.
- Large regional differences were estimated in the cost per tonne ($\$/tCO_2e$) of emission reductions. Per unit costs were significantly lower in Ontario than in the semi-arid prairies.

- Government goals and the policies and programs that support those goals should be refocused on a comprehensive cropping system approach to carbon accounting and emission reduction aimed at sustainable intensification and reducing the carbon intensity of Canadian crops.
- Climate change is a serious issue. Government, industry, and farmers need to work together to continue to adopt climate smart agriculture practices and targets that reflect the realities of Canadian agriculture. This requires a comprehensive approach to managing GHG sources and sinks on the farm rather than focus on a single emission source.

This study focused on adoption of 4R BMPs with broad applicability and reasonably well-known costs. We used reasonable N rate reductions with the BMPs to simulate improved nitrogen use efficiency, and moderately aggressive reduction modifiers to simulate the emission reduction effects of source, time, and place. We did not model all possible BMPs and using different BMP combinations and different assumptions concerning crop prices, fertilizer prices, operational costs, and fixed costs would undoubtedly result in somewhat different numbers. However, in our opinion they would not significantly alter the trends or change the conclusions reported here.